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American Inst. of Biological Sciences, Arlington, Va.

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ANALYSIS OF SPECIALIZED PESTICIDE PROBLEMS

INVERTEBRATE CONTROL AGENTS - EFFICACY TEST METHODS

VOLUME IV

LIVESTOCK, POULTRY, FUR & WOOL BEARING ANIMALS

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16. Abstracts This report presents techniques used by researchers to determine the efficacy of insecticides applied to livestock (cattle, horses, sheep and goats, swine and poultry) for the control of the major arthropods that parasitize these animals. Also included are techniques used to determine the effectiveness of insecticides applied to litter, bedding, limited livestock inhabitation areas, and livestock manure. This listing of techniques is not intended to eliminate other procedures to determine efficacy of insecticides for the control of the same arthropod parasites. The compilation of these listed techniques revealed areas in which adequate testing procedures were not available. This report is divided accrding to the five major commodity groups.

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screwworms
horse bots
sheep and goat lice
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ANALYSIS OF SPECIALIZED PESTICIDE PROBLEMS
INVERTEBRATE CONTROL AGENTS - EFFICACY TEST METHODS
VOLUME IV
LIVESTOCK, POULTRY, FUR & WOOL BEARING ANIMALS

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Report To The
Environmental Protection Agency

By The

American Institute of Biological Sciences
Arlington, Virginia 22209

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LIVESTOCK, POULTRY, FUR AND WOOL BEARING ANIMALS

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INTRODUCTION

This report presents techniques utilized by researchers to determine the efficacy of insecticides applied to livestock (cattle, horses, sheep and goats, swine and poultry) for the control of the major arthropods that parasitize these animals. Also included are techniques utilized to determine the effectiveness of insecticides applied to litter, bedding, limited livestock inhabitation areas, and livestock manure.

The listing of these techniques is not intended to eliminate other procedures to determine efficacy of insecticides for the control of the same arthropod parasites. The compilation of these listed techniques revealed areas in which adequate testing procedures were not available. Other techniques, may be equal to or better than the listed techniques in determinimg efficacy of insecticides.

Of major importance in the selection of techniques for inclusion in this report were 2 factors: (1) Is the technique of application and amount of insecticide applied so carefully defined and recorded that the dosage of insecticide to which the arthropods were exposed can be determined? (2) Are the infestations of arthropods so measured that the response of the arthropods to the treatment can be evaluated? The development of accurate and reliable data depends on these two factors.

The basic premise underlying testing for efficacy is the realization that infestations of arthropod parasites will respond in a similar manner to a known amount of insecticide applied to an animal or its environs. Although this response is not completely consistent, it, as well as the dosage, must be measured with accuracy and consistency in order to obtain meaningful data on the response. Thus, tests should be designed so that changes in a population of an arthropod parasite that are due to factors other than the specific dosage of insecticide can be determined as well as the changes in the infestation due to the insecticidal treatment.

This report is divided into divisions according to the five major commodity groups. Each division is divided into two sections.

Section A "Treatment and Evaluation Techniques" delineates the biological and chemical information needed to evaluate candidate compounds for livestock parasite control. The major species or groups and standard or suggested techniques to determine their populations or infestations are listed. The number of animals (or other parasite habitats) to be sampled has been suggested because the number of animals given a treatment can range from one to a flock of thousands. The examination times suggested are those that are generally used. In the discussion on control groups and standard treatments, the practicality of maintaining control groups or untreated animals is presented. It is important that the numbers of animals in the control or standard treatment groups be equal to numbers of

animals in a treatment group in small scale tests; in large-scale tests, only a small portion of the animals need to be untreated or given a standard treatment. It is most important that the control or standard treatment groups contain animals of the same general size, age, condition, groups and have similar infestation of parasites or be exposed to similar populations of arthropod parasites. The criteria for determining the effectiveness of the treatment(s) are listed. Finally, section A contains a compilation of the techniques of application of insecticides to animals or other targets. A technique is listed only once for each commodity group but may be used to apply insecticides for the control of a number of parasites.

Whenever possible, published techniques are briefly presented and the literature citation given.

Section B, "Test Reporting", contains a suggested outline for reporting details of the test.

I. Cattle (Beef and Dairy)

Cattle are parasitized by a variety of insects, ticks, and mites that suck blood, annoy and irritate animals, transmit diseases, damage hides, stunt growth, decrease production of milk, lower resistance of animals to diseases, and cause death of animals. Insecticides are applied to both beef and dairy cattle to control these arthropods and to avoid these losses. Usually, treatments that effectively control arthropod parasites on beef cattle will also control those same parasites on dairy cattle.

A. Treatment and Evaluation Techniques

1. Cattle Grubs

Cattle grubs are the larvae of heel flies that lay eggs on hairs of animals. The reaction of cattle running from the ovipositing females is called "gadding". Larvae hatch from the eggs, penetrate the animal's skin, and migrate through the animal's body and later are found encysted in the animal's back. (The swellings in the animals' backs are called "warbles" or "wolves".) Grubs spend 30-40 days in the back before leaving to pupate in the ground. The life cycle of the cattle grub takes about 1 year with certain events such as egg laying, migration of larvae through the body, and formation of warbles in the hide taking place at about the same time of the year. Time of appearance of these various stages depends upon the geographical location in the United States. Cattle are essentially the only hosts for cattle grubs, although bison and horses may be infested.

The cattle industry loses millions of dollars each year to cattle grubs because of decreased weight gains, milk flow due to gadding, excessive trimming of the carcass especially from the backline infested with cattle grubs, and down-grading of hides damaged by cattle grubs.

For many years the standard method of control of cattle grubs has been the application of insecticides onto grubs in warbles in the animals' backs. This method has been replaced in recent times (since 1957) by treatment of cattle with animal systemic insecticides that are applied after the end of heel fly activity and kill migrating larvae and prevent them from reaching the animals' backs. The extensive literature on the development and use of animal systemic insecticides has been reviewed by Bushland et al. (1963) and Khan (1969).

a. Species: Cattle in the United States are infested with 2 species of cattle grubs: the northern cattle grub, *Hypoderma bovis* (L.), is found in Canada and throughout the United States south to a line from California to Oklahoma to Virginia, and the common cattle grub, *H. lineatum* (de Villers), is found in cattle throughout the United

States, Canada, and Mexico. Life history of these 2 species is similar with minor exceptions. In areas where both species are found, the *H. lineatum* cycle is usually slightly earlier in the year than the *H. bovis* cycle. Adults and third instar larvae can be easily separated by species. Although no differences in susceptibility of the 2 species to treatment have been recorded, it is necessary to know the species in the test cattle.

b. Population Determination: Numbers of cattle grubs in cattle are determined by examining the backs of the animals and recording numbers of larvae in warbles.

c. Sample Size: The size of the sample of cattle to be examined for cattle grubs depends basically upon the size of the treatment groups. A suggested number of cattle examined is as follows:

No. of Cattle Per Treatment	No. of Cattle Examined
3-20	All
21-100	50% (minimum of 20)
>100	50

Animals examined should be of the same general age and condition as the entire treatment group. Usually younger animals, less than 2 years old, are more heavily infested than older animals.

d. Examination Times: In tests with systemic insecticides, there are 2 general regimes for examination of cattle for the appearance of cattle grubs in the animals' backs. In one regime, the animals are examined monthly during the 4 to 6-month period of warble formation, and as grubs appear in the animals' backs they are located on an outline map of the back of each animal. At each monthly examination, as new grubs appear, they are also located on the map. In this manner, cumulative counts of grubs that appear in each animal's back can be obtained (Drummond 1960).

In another regime, cattle are examined once or twice possibly more) during the period when warbles are being formed in the animal's back. Counts should be separated by 60 days so that grubs counted at the first examination will not be counted at the second. Cattle should be examined when peak numbers of grubs normally are found in animals' backs. Add the counts together in order to determine total numbers of grubs in each animal's back. (Drummond1959a, Rogoff et al. 1960).

In areas where both species of cattle grubs appear in animal's backs at about the same time of the year, sufficient counts and identification of grubs in warbles should be made in order to establish efficacy of treatments for both species.

In tests with materials applied to animals to kill larvae that have formed warbles in the animal's back, warbles should be located on a map, the animals treated, and then the backs of the animals examined at 4-7 days after treatment and grubs extracted from the animals' backs to determine the number of grubs that have been killed by the treatment (Smith and Richards 1954). The animals may be examined 1 month after treatment to determine whether the treatments prevented new grubs from appearing in the backs of the animals.

e. Controls (Standard Treatment): In order to determine the effectiveness of treatments with animal systemic insecticides to prevent cattle grubs from appearing in the backs of cattle, it is essential that a group of animals of the same age and from the same herd that is treated be maintained as untreated controls. If possible, one group of animals equal in size to a treated group should be given a standard treatment. In very large-scale tests to demonstrate area control, it may be necessary to treat all the cattle on a ranch. In this type of test, untreated animals may be removed from the ranch and cattle grubs counted elsewhere, or untreated animals may be held on ranches outside the treatment area (Rich 1965). In tests with insecticides applied to the backs of cattle to kill encysted grubs, a group of untreated animals should be maintained along with treated animals in order to determine natural mortality of grubs in the animals' backs and also to compare numbers of grubs that appear in treated animals' backs.

f. Experimental Design: In tests with animal systemic insecticides to prevent larvae from appearing in animals' backs, cattle are treated after the end of heel fly season and before grubs appear in the animals' backs. Effectiveness of the treatments is determined by comparing the numbers of grubs that appear in the backs of treated animals with numbers that appear in the backs of untreated animals from the same herd.

In tests to determine effectiveness of materials applied to backs after grubs have appeared, animals are treated, and effectiveness of treatments is determined by extracting grubs and determining mortality of extracted grubs.

g. Treatment Techniques: Cattle are treated in a variety of ways with animal systemic insecticides for the control of cattle grubs.

(1) Single Oral Dose: Animal systemic insecticides may be administered orally as drenches, boluses, or in capsules (Drummond 1960). Care should be taken that animals receive the entire dose. Record the formulation, final concentration of active ingredient, total amount administered, and dosage in terms of mg of active ingredient per kg of body weight of animal (animals should be weighed if possible).

(2) Feed Treatment: Animal systemic insecticides may be administered to animals as part of a feeding regimen. Insecticides may be mixed into the entire feed ration (Kohler et al. 1959) or fed in a small amount of feed which, when consumed, is followed by untreated feed (Drummond and Moore 1960). Record the formulation, final concentration of active ingredient (ppm in feed), or total mg of active ingredient per kg body weight of animal, amount of feed or treatment consumed, length of treatment period.

(3) Water Treatment: Animal systemic insecticides may be administered to cattle through drinking water (Dobson and Sanders 1963). If a number of cattle are treated, the entire volume of drinking water may be treated, or individual cattle may be offered treated drinking water and, when the treated water is consumed, given untreated water. Record the formulation, final concentration of active ingredient in terms of ppm in water or mg of active ingredient per kg of body weight of animal, average consumption of water per animal, and length of treatment period.

(4) Mineral, Salt, or Protein Supplement: Animal systemic insecticides may be formulated at low concentrations in mineral, salt, or protein supplements and offered free choice to cattle (Rogoff and Kohler 1959, Medley et al. 1963). Because consumption of salt, mineral, and protein supplement varies considerably from animal to animal, it is important to determine whether or not all animals consumed treated materials. Record formulation, final concentration of active ingredient in terms of percentage or ppm of treated supplement, average consumption per animal per day, dosage in terms of mg active ingredient per kg body weight per day, and length of treatment period.

(5) Injections: Animal systemic insecticides may be given to animals in the form of intramuscular, intraperitoneal, or subcutaneous injections (Drummond 1959b, Kohler and Rogoff 1962). Record formulation, amount of material injected per animal, location of injection, and dosage in terms of mg of active ingredient per kg of body weight.

(6) Whole-Body Sprays: Animal systemic insecticides may be applied to animals as whole-body sprays. Care should be taken that animals are treated thoroughly and that enough pressure is used to penetrate hair coat and assure wetting of the skin (Rogoff et al. 1960). A variation of the whole-body spray is the use of a spray-dip machine to apply spray to cattle (Drummond et al. 1965). Record formulation, final concentration of active ingredient, equipment used and application techniques (pressure, nozzles, etc.), and average volume of spray applied per animal.

(7) Dip: Animal systemic insecticides may be used to charge dipping vats in which cattle may be dipped (Scharff and Ludwig 1961, Drummond 1963). It is important that the animals be immersed thoroughly in

the dip fluids. Record formulation, final concentration of active ingredient, volume of liquid in the vat, age of charge at time of dipping, number of cattle dipped, and data on recharging if necessary. Chemical analyses of active ingredient in vat fluids before and after dipping are necessary in order to determine actual amount of active ingredient in the vat fluid.

(8) Pour-on Treatment: Animal systemic insecticides may be applied to cattle by the pour-on technique in which a small amount of insecticide is applied to the backline of cattle. In the pour-on technique, ready-to-use formulation or an emulsifiable concentrate diluted with water or oil are poured down the backline of cattle in ounce rates (Rogoff and Kohler 1960). In an extension of this technique, ready-to-use formulations are applied to a spot on the backline at milliliter rates (Loomis et al. 1973). Record formulation, diluent, final concentration of active ingredient, amount applied per animal, area treated, and dosage based on mg active ingredient per kg body weight of animal.

(9) Dust: Animal systemic insecticides may be applied as dusts contained in dust bags and placed in the pasture for free-choice use or placed in openings to feed, mineral, and/or water sources so that cattle are forced to use them on a daily basis (Matthysse et al. 1968, Lloyd 1971). With cattle grub control, it is important that dust bags be located so that animals are forced to treat themselves on a daily basis to insure that sufficient insecticide is applied for grub control. In tests with dust bags for control of ectoparasites, such daily treatment is not essential. Record formulation, final concentration of active ingredient, average amount of dust used per animal, location of dust bags, and length of treatment period.

In tests to control cattle grubs in the animal's back, the animal may be treated with <u>contact insecticides</u> as follows:

(1) Back Spray: The animals' backs should be sprayed thououghly with the insecticide. Care is taken to force insecticide into the warble openings in the animals' backs. Record formulation, final concentration of active ingredient, equipment used, and application techniques (pressure, nozzles, etc.) and average volume of spray applied per back.

2. Horn Flies

Probably the most important fly affecting cattle in the United States is the horn fly. Populations of these small flies that appear on cattle in early spring and remain on animals until frost in the fall may reach levels of 3000/animal and as high as 20,000/bull (Laake 1946). Adult flies suck blood from cattle as many as 20 times/day and mate on the host.

Females lay eggs in fresh cattle manure. Adult horn flies are found principally on cattle but may be found occasionally on horses and other large mammals. Heavy infestations cause considerable discomfort to cattle; animals move restlessly, continuously switching their tails and throwing their heads in order to brush off flies. Heavily infested animals may show lesser weight gains when compared with gains of treated animals. Most ranchers treat cattle for the control of horn flies.

a. Species: The horn fly is *Haematobia irritans* (L.).

b. Population Determination: In tests with topical application of insecticides for the control of adult horn flies, the standard technique is to estimate the number of horn flies per animal. This estimation is accomplished by examining a number of animals in the herd, usually with the aid of binoculars, and counting or estimating numbers of horn flies on the animals. Flies are counted or estimated on both sides of an individual or on one side of an animal and reported as "flies/side". In tests with orally administered insecticides for the control of larval horn flies in cattle manure, in addition to estimating the number of adult horn flies on cattle, freshly dropped manure pats may be covered with emergence cages, and numbers of adult horn flies that emerge are counted (Kunz et al. 1973).

c. Sample Size: It is difficult to count or estimate horn flies on all of the cattle in a treatment group unless small treatment groups are maintained. The following is a suggested sampling:

No. of Cattle per Treatment	No. of Cattle Examined for Horn Flies	No. of Manure Pats Covered or Collected
3-10	All	5
11-100	20% (Minimum of 10)	10
>100	20	20

Because of the differences in infestation rates of horn flies on bulls, cows, and calves, it is important to try to count flies on the same animals before and after treatment. In tests with materials added to feed or water for control of horn fly larvae in manure, manure samples should be collected before treatment and at intervals after treatment to determine whether horn fly larvae are killed in the manure pats.

d. Examination Times: Cattle should be examined and manure pats should be covered or collected at least once before treatment and usually twice a week after treatment. In tests with continuous treat-

ment, cattle should be examined and manure pats covered or collected at weekly or biweekly intervals during the treatment period.

e. Control (Standard Treatment): Because of the mobile nature of these flies, it is necessary that all animals in the same pasture be treated with the same treatment. Similar animals in adjoining pastures may be treated with a standard treatment, other treatments, or contain untreated control animals. The more that a treated group is isolated from untreated cattle, the less the reinfestation pressure.

f. Experimental Design: In tests with adulticides, numbers of horn flies on treated cattle are compared with numbers on the same animals before treatment and with numbers on nearby untreated control cattle. In certain tests (Roberts 1959), untreated controls were not maintained, but treatments were considered to have failed when the average number of horn flies per animal exceeded 25. In tests to control larvae, effectiveness can be determined by counting numbers of horn flies on the cattle before and during treatments. More realistically, because activity in the manure against larvae can be obscured by the migration of flies onto treated cattle, effectiveness should be determined by comparing numbers of horn flies that emerge from manure collected from the same animals before treatment or from nearby animals collected at the same time after treatment. In addition, manure samples can be subjected to a bioassay technique in which samples are infested with known numbers of horn fly eggs or larvae and number of adults that emerge are recorded. Effectiveness is determined by comparing number of horn flies that emerge from treated manure with numbers from untreated manure.

g. Treatment Techniques: Cattle are treated in a number of ways to control horn flies. The techniques of application of insecticides for treatment of cattle in section I, A, 1, g, (2), (3), (4), (6), (7), (8), (9) can be used to apply insecticides for the control of adult horn flies. Of special interest are use of self-applicating dust rubbers (Hargett and Turner 1958), dust bags (Poindexter and Adkins 1970, Knapp 1972), hand dusting (Lindquist and Hoffman 1954), pen spraying (Hoffman and Roberts 1963), and pour-on (Rogoff et al. 1963, Rogoff and Kohler 1961). In the application of pour-on for horn fly control, a standard amount, e.g., 100 ml/animal, may be applied rather than a specific mg/kg dosage as with animal systemic insecticides.

In addition, there are the following treatments:

(1) Backrubbers: Backrubbers are commercially available or may be constructed of chain or cable wrapped with lengths of burlap and treated with a suspension, emulsion, or solution of insecticide in no. 2 diesel oil or other diluent (Rogoff and Moxon 1952). Backrubbers are positioned in pastures so that animals may rub against them at

free choice or may be positioned in entrances to watering troughs, salt or mineral blocks, etc., so that cattle are forced to use them on a continuous basis. Record formulation, final concentration of insecticide, diluent, type of backrubber construction, amount of material applied per meter of backrubber, location of backrubber, use, and length of treatment period.

(2) Low-Volume Application: Insecticides may be applied to cattle with low-volume sprayers that dispense mist sprays of 5-150 ml of insecticide per animal daily. (Hoffman et al. 1965). Application devices can be placed in doorways of animal facilities through which animals are forced to pass daily. Record formulation, final concentration of insecticide, diluent, details of apparatus and application, and average amount of spray per animal per day.

(3) Ultra-Low-Volume Application: Automatic sprayers can be used to apply less than 5 ml of insecticide/animal (Eschle and Miller 1968). These sprayers should be situated where cattle pass so that animals can be treated automatically on a daily basis. In another type of ULV technique, unrestrained cattle were treated with insecticides dispensed from an ULV applicator in a pickup truck (Kinzer 1970) or dispensed from an airplane (Kantack et al. 1967, Kinzer 1969). Record formulation, diluent, final concentration of insecticide, details of equipment, average amount of insecticide applied per animal, length of spray period (for automatic sprayers) or amount of insecticide applied per hectare, number of cattle and numbers of treatments (for ground and aerial application).

(4) Wax-Bar Application: Harvey and Ely (1969) described a technique in which an insecticide was incorporated into a wax bar and the bar rubbed onto the backs of animals. Record the formulation, final concentration of insecticide, configuration of bars, amount of bar per animal, and insecticide per animal.

Materials may be given to cattle for the control of larvae of horn flies in manure orally in feed, water, and mineral similarly to techniques used to administer animal systemic insecticides in feed, water, and mineral for the control of cattle grubs. Treatment may be administered utilizing techniques in section I, A, 1, g, (2), (3), (4).

3. Other Biting Flies

In addition to horn flies, there are a number of other blood-sucking flies (often called biting flies) that attack cattle. These flies annoy animals and interfere with normal feeding activities, in that cattle may band together to aid each other in protecting themselves from these flies. Heavy infestations cause considerable loss of blood, reduced weight gains, increased susceptibility to diseases, and even death of cattle. These biting flies may spread such diseases as anaplasmosis, anthrax, tularemia, bluetongue, and other diseases of cattle. Because they are found on cattle only when feeding, biting flies are generally very difficult to observe, evaluate, and control.

a. Species: There are a number of species of biting flies that attack cattle and other livestock. Of particular interest is the stable fly, *Stomoxys calcitrans* (L.), that is found around cattle held in pens and other confined situations. Larvae of this species are found in animal and feed wastes. Other biting flies belong to the family Tabanidae, the horse flies and deer flies. These large flies may be found in marshy, coastal areas in abundance. They feed intermittently on cattle and may cause considerable damage for brief periods of time. Flies of the family Simuliidae, the black flies or buffalo gnats, are very small flies that usually feed in the ears and around the head of cattle. They may reach epidemic numbers, and their feeding activities may weaken animals and even cause death. Flies of the family Ceratopogonidae, often called "punkies" or no-see-ums", are tiny flies that prefer to feed in the ears of cattle. These flies often may reach epidemic populations. Finally, members of the family Culcicidae, the mosquitoes, suck blood from cattle and transmit diseases and cause weight loss (Steelman et al. 1972, 1973). It is necessary to capture representative samples to determine the test species.

b. Population Determinations: Populations of biting flies are determined by observing the numbers of each species feeding on cattle. It is important to observe animals at a specific time of the day because of the variation in time of feeding of the different species of flies. With stable flies, usually flies observed feeding on the inside of one leg and the outside of the other leg are counted for a specific period of time (Campbell and Hermanussen 1971). Techniques to determine populations of other biting flies feeding on cattle have not been well defined.

c. Sample Size: Since it is difficult to count biting rates, the following sampling of animals is suggested:

No. of Cattle per Treatment	No. of Cattle Observed
3-10	All
11-100	20% (minimum of 10)
>100	20

d. Examination Times: Because insecticides applied to cattle for the control of biting flies are generally effective for only short periods of time, animals are usually examined before treatment and daily after treatment.

e. Controls (Standard Treatment): Untreated animals should not be pastured in the same pasture with treated cattle. Untreated cattle and cattle given standard treatments should be pastured near treated cattle so that they will be exposed to the same population pressures.

f. Experimental Design: Effectiveness of treatments is determined by comparing the feeding rates of flies before treatment with the feeding rates of flies on the same cattle after treatment. In addition, feeding rates on treated animals after treatment can be compared with feeding rates on untreated animals taken at about the same time.

g. Treatment Techniques: The techniques listed in I, A, 1, g, (6), (7), (8), (9), and I, A, 2, g, (1), (2), (3), may be used to apply insecticides to cattle for the control of other biting flies. Campbell and Hermanussen (1971) applied residual sprays to resting sites in the barnyard for control of stable flies. In addition, they applied whole-body sprays to cattle and mist-blower low-volume applications to cattle in feedlots. Insecticides may also be applied at low-volume or ultra-low-volume rates from helicopters and fixed-wing aircraft to cattle in feedlots and other confinements (Campbell and Raun 1971). *Hippelates* gnats and other flies were controlled by low-volume application of insecticides to breeding sites (Axtell 1971). A review of techniques to apply ULV treatments to cattle and rangeland was presented by Lofgren (1970).

4. Face Fly

The face fly, although a recent introduction to the United States from Europe, has spread rapidly from the northeastern states to almost all of the contiguous 48 states. Whenever new infestations of the face fly are found, it often becomes a major pest of cattle in the newly-infested areas. Once established in an area, it continues to be a major pest. The face fly, a relative of the house fly, has the habit of frequenting the moist areas, eyes, nostrils, etc., of the face of cattle (and horses). This characteristic makes it difficult to control and allows the face fly to contribute to the spread of pinkeye, the eye worm (*Thelazia* spp) and other ailments of the eyes of cattle. Females leave the host to lay eggs in fresh manure where larvae develop. Ode and Matthysse (1967) present a review of the literature and a comprehensive study on the bionomics of the face fly.

a. Species: The only species is *Musca autumnalis* DeGeer, the face fly.

b. Population Determination: The usual techniques are to observe cattle and count the number of face flies on the head or whole animal. McGuire and Sailer (1962) determined that counting of the face flies around the eyes is statistically sound for computing the total fly count on a given animal.

c. Sample Size: Suggested numbers of cattle to be examined for face flies is as follows :

No. of Cattle per Treatment	No. of Cattle Examined for Face Flies
3-10	All
11-100	20% (minimum of 10 animals)
>100	20

d. Examination Times: Because the effectiveness of single treatments for the control of the face fly is usually shortlived, it is necessary to count the number of flies immediately before treatment and daily or 2 to 3 times a week after treatment. If multiple treatments are used, it may be necessary to count flies between treatments and after the last treatment. If continuous treatments are tested, flies may be counted at intervals during the treatment period.

e. Controls: In small-scale tests, untreated controls should be maintained in separate pasture but on same farm. Also, the same farm may contain pasture with a group of animals treated with a standard treatment. In large-scale tests, it may not be possible to have untreated animals on the same ranch as treated animals, but untreated animals may be maintained in similar pastures nearby.

f. Experimental Design: Effectiveness of the treatments is determined by comparing the numbers of face flies per animal before treatment with numbers of flies on the same animals after treatment, or numbers on treated animals after treatment can be compared with numbers of flies on untreated animals observed at about the same time.

g. Treatment Techniques: A number of standard dermal treatments [see section I, A, 1, g, (6), (7), (8), (9), I, A, 2, g, (1), (2), (3)] have been applied to the face and body of cattle for the control of face flies. Cattle have been treated with whole-body sprays, hand dusting, self-treatment dust bags or backrubbers, (Turner 1965, Poindexter and Adkins 1970, Wrich 1970, Kessler and Berndt 1971), and aerial application of ULV insecticides (Del Fosse and Balsbaugh 1974).

Other treatments for the control of the face fly have been the application of repellents or toxicants as smears, baits, ointments, and face wipes to the faces of individual animals (Bruce et al. 1960, Ode and Matthysse 1964a). Record formulation, diluent, final concentration of active ingredient, type and location of application, and amount of material applied per animal.

Insecticides may be incorporated into the feed of cattle in order to control face flies in the manure of the animals (Ode and Matthysse 1964b, Lloyd and Matthysse 1970). Jones and Medley (1973) fed insecticide to cattle or allowed infested cattle to graze on insecticide-treated pasture.

Bioassay techniques similar to those used with the horn fly I, A, 2, f, can be used to evaluate orally administered treatment for control of face larvae in manure.

5. Lice

Cattle in most areas of the United States are infested with biting lice and a variety of sucking lice. Infestations of lice cause lowered milk production and reduced weight gains in cattle and may be a contributing factor to death. Animals heavily infested appear in poor condition and have large areas rubbed free of hair with the remaining hair coat rough and matted in appearance. Heavy infestations of sucking lice cause marked anemia in cattle.

Oftentimes a small number of animals in a herd tend to be more heavily infested than the majority of the herd. The animals, called "carriers", may act as a reinfestation focus for the less heavily infested animals. Populations of lice vary according to season, and lice are usually most numerous in the cooler times of the year. Excellent reviews of biology and control of cattle lice have been presented by Imes (1974) and Matthysse (1946).

a. Species: Five species of lice have been recorded from domestic cattle. One is the cattle biting louse, *Bovicola bovis* (L). The remainder are sucking lice -- the shortnosed cattle louse, *Haematopinus eurysternus* (Nitzsch), the longnosed cattle louse, *Linognathus vituli* (L.), the little blue cattle louse, *Solenopotes capillatus* Enderlein, and the cattle tail louse, *H. quadripertusus* Fahrenholz. Because of their large size, these lice can readily be distinguished; although similar, there should be no confusion between *H. eurysternus* and *H. quadripertusus* (Melany and Kin 1974).

b. Population Determination: The only technique to estimate the populations of lice on cattle is to examine areas of skin on the animal's body for lice. Because of the large body surface area of cattle, it is impossible to examine all sites of infestation. In addition, each species of cattle lice inhabits specific locations. Most authors have presented systems in which they rated infestations of lice according to the ease of finding them, the number per square inch examined and appearance of lice and hair coat, etc. (Matthysse 1946, Collins and Dewhirst 1965, Hoffman et al. 1969, Buchanan and Coles 1971).

c. Sample Size: The following sampling is suggested:

No. of Cattle per Treatment	No. of Cattle Examined for Lice
3-10	All
11-100	20% (minimum of 10 animals)
>100	20

It is suggested that cattle be examined before treatment to find heavily infested animals. These animals should be marked clearly so that they can be examined after treatment.

d. Examination Times: Animals should be examined before treatment and weekly intervals after treatment. If multiple treatments are used, animals should be examined between treatments and after the last treatment. If continuous treatments are being tested, animals should be examined weekly or biweekly during the treatment period.

e. Controls (Standard Treatment): In most tests, controls should be maintained separately from groups of treated animals. In addition, a group of animals treated with a standard treatment should also be maintained separately from treated animals. In large-scale tests, usually all animals in a pasture are treated with the same treatment.

f. Experimental Design: In most tests effectiveness of the treatments is determined by comparing rates of infestations of lice on the same animals before treatment and after treatment. Rates of infestations on treated animals can be compared with rates on untreated animals.

g. Treatment Techniques: Insecticides can be applied to cattle for the control of lice by a variety of treatment techniques already presented [Section I, A, 1, g, (6), (7), (8), (9), I, A, 2, g, (1), (2), (3)]. In addition, Harvey and Ely (1968) presented a technique in which infested cattle were placed individually in a shed that also contained resin strips impregnated with a vaporizing insecticide. Record formulation, final concentration of active ingredient, details of exposure conditions, amount of resin strip tested, and exposure period. Butler (unpublished) evaluated insecticides for the control of the cattle tail louse by treating the animals completely, with special care exercised to treat tails. In addition, he evaluated insecticides by dipping the tail of animals in the insecticide. Record formulation, final concentration of active ingredient, details of testing procedure, and amount of material used per animal. Roberts et al. (1969) fed a systemic insecticide to determine activity against shortnose sucking lice.

6. Ticks

Cattle are parasitized by a number of species of ticks. On a worldwide basis, ticks are the most important parasites of cattle. Ticks suck blood from animals, predispose them to other parasites, inject toxins, damage hides, and cause "tick worry", and transmit a number of severe and often fatal diseases of cattle. Ticks may become so numerous that cattle appear listless, their hair coat becomes matted and rubbed, they may not graze normally, and they may suffer severe anemia. In many areas of the United States, it is necessary to control ticks for the health of the cattle. Usually, ticks on cattle are controlled by the application of insecticides to infested animals. Grazing areas may be treated with insecticides for tick control, but techniques for ground application will not be reviewed in this compendium.

a. Species: Each area of the United States has a specific fauna of ticks that affect lifestock. Most species are found in southern States, although some species are found in both northern and southern States. In most areas the tick fauna on cattle will vary from season to season. Of the variety of the ticks found on livestock, the following are the most important:

Amblyomma americanum (L.), the lone star tick, a 3-host species found on cattle in the spring and generally distributed throughout the southeastern third of the United States; *Amblyomma maculatum* Koch, the Gulf Coast tick, a 3-host species found attached in and near the ears of cattle in the summer and limited in distribution (except for Oklahoma and neighboring states) to States around the Gulf Coast and southern Atlantic Coast; *Dermacentor albipictus* (Packard), the winter tick, a 1-host species often found in large numbers on cattle in the fall and winter and widely distributed in most northern and central southern States; *Dermacentor andersoni* Stiles, the Rocky Mountain wood tick, a 3-host species found in the summer on cattle in northwestern States; *D. occidentalis* Marx, the Pacific Coast tick, a 3-host species found in the spring and summer on cattle distributed along the Pacific Coast; *D. variabilis* (Say), the American dog tick, another 3-host species found sparsely in the spring and summer on cattle in the eastern two-thirds of the United States; *Ixodes scapularis* Say, the blacklegged tick, a 3-host species found in low numbers in the late winter and early spring on cattle in the south central States; and *Otobius megnini* (Duges), the spinose ear tick, a 1-host species found at all seasons in the ears of cattle in most areas of the United States.

b. Population Determination: In tests with insecticides for the control of ticks, populations of ticks on cattle are usually determined by the examination of specific body areas of animals for attached ticks (Hoffman et al. 1969). Drummond et al. (1959, 1960) counted numbers of adult lone star ticks and winter ticks on the dewlap and escutcheon of each animal confined in a chute. Roth and Eddy (1966) counted adult Rocky Mountain

wood ticks attached to the brisket and nearby areas, especially the lower part of the neck. Numbers of Gulf Coast ticks were counted in and around ears of cattle by Gladney et al. (unpublished). In tests with spinose ear ticks, Drummond et al. (1967a) removed ticks from ears of cattle with a wire loop; Harvey and Brethour (1961) counted ticks in ears.

c. Sample Size: The following sample size is suggested:

No. of Cattle per Treatment	No. of Cattle Examined for Ticks
3-10	All
11-100	20% (minimum of 10 cattle)
>100	20

d. Examination Times: In most tests with insecticides applied to cattle for the control of ticks, animals are usually examined for ticks before treatment and at weekly or monthly intervals after treatment. In tests with the ear tick, animals were examined at 1 week and 1 month posttreatment (Drummond et al. 1967a).

e. Controls (Standard Treatment): In order to determine changes in natural populations of ticks, a group of animals of the same general type as those in treated groups should be maintained in the same pasture as controls. If possible, one group of animals should be treated with a standard treatment. In large-scale tests, it may not be possible to have untreated animals available in the same pasture.

f. Experimental Design: Effectiveness of treatments applied to cattle for the control of ticks is determined by comparing the average number of ticks counted before treatment with the average number of ticks counted after treatment on the same animals or with average number counted on untreated controls at the same posttreatment intervals. Untreated controls may not be part of the evaluation technique; rather they can be used to determine natural dynamics of tick populations.

g. Treatment Techniques: The most common treatment of cattle for the control of ticks with insecticides is the use of dips and sprays, which involves the thorough treatment of the animals' bodies. See section I, A, 1, g, (6), (7), (8), (9), I, A, 2, g, (1), (2), (3) for details. Other treatment techniques have been pour-on (Drummond et al. 1967b) and feeding animals systemic insecticides (Drummond et al. 1972; Harvey and Brethour 1961). Gladney et al. (unpublished) evaluated a number of techniques, including dust bags, smears, ointments, insecticide-impregnated collars, ear bands, and ear tags for the control of Gulf Coast ticks. In tests with spinose ear ticks, Drummond et al. (1967a) applied dusts, pour-ons, aerosols, smears, and ointments directly into the ears of cattle.

7. Scab and Mange Mites

In the United States, cattle are infested with at least 5 species of scab and mange mites that live on or in the skin and cause severe dermatitis that consists of a thickening of the skin and the formation of lesions and scabs at the sites of infestations. Cattle react to scab mite infestations by biting, rubbing, and scratching infested areas. Heavy infestations of scab and mange cause loss in vitality, decreased weight gains, and may lead to the death of animals. An excellent review of the species, biology, and control of cattle scab is presented by Kemper and Peterson (1953). Because of the contagious nature of the infestation, certain scab mites are subjects of ongoing eradication campaigns, which include compulsory treatment and quarantine. Therefore, if scab is suspected in cattle, it should be reported to State and Federal regulatory authorities.

a. Species: In the United States, there are 5 species of mites that cause cattle mange or scab. The most important from a quarantine and damage basis is the common scab mite, *Psoroptes ovis* (Hering). In addition, cattle may also be infested with the sarcoptic scab mite, *Sarcoptes scabiei bovis* (DeGeer). Cattle may also be infested with a less virulent scab mite, the chorioptic scab mite, *Chorioptes bovis* (Hering). In addition, another less prevalent mite, *Psorergates bos* Johnston, has been found on cattle and may be widely distributed although not detected (Roberts and Meleney 1965). Finally, cattle are infested with demodectic mange mites, *Demodex bovis* Stiles. These mites are very common and cause lesions that can be readily identified in pickled cattle hides (Fisher 1974).

b. Population Determinations: The only method of determining infestation with mange is to scrape lesions on cattle and examine the scrapings for mites with the aid of magnification. At that time, both numbers and species of mites can be determined. However, population determinations are usually limited to determining whether or not the animals are infested with mites.

c. Sample Size: The following sampling sizes are suggested:

No. of Cattle per Treatment	No. of Cattle Examined for Mange Mites
3-10	All
11-100	20% (minimum of 10 cattle)
>100	20

It is extremely important in these tests to examine carefully all cattle before treatment, mark those that are infested, and be sure to examine those same infested cattle at the post-treatment examinations.

d. Examination Times: Animals should be examined before treatment and during treatments if multiple treatments are administered, and then within 1 week after treatment and monthly thereafter to determine whether animals become reinfested. These long posttreatment examination intervals are necessary because of the difficulty in determining whether or not animals are infested.

e. Controls (Standard Treatment): Because of the highly contagious nature of scab and mange, it is necessary to separate treated animals from untreated animals and from animals given a standard treatment. In large-scale tests, it may not be possible to maintain untreated animals on the same premises, but untreated (but infested) cattle could be maintained on nearby premises so as to determine natural changes in infestation rates.

f. Experimental Design: Effectiveness of treatments for the control of mange on cattle is determined by comparing infestation of animals before treatment with infestation of these same animals after treatments. Care should be taken to keep the cattle in the same environment before and after treatment. Cattle that are moved often lose their infestation.

g. Treatment Techniques: The most commonly used and recommended method is to treat cattle by dipping them in insecticides in dipping vats. It is necessary to thoroughly immerse the animals to make sure that all body areas are treated completely [see section I, A, 1, g, (7)]. In areas where dipping vats are not available, animals may be sprayed thoroughly with high-pressure equipment so that the animals are wet thoroughly to the skin (Smith 1967), however, Matthysse et al. (1967) used a mist blower to apply 2-8 oz insecticide/cow and achieved control of *Chorioptes bovis*. In certain instances (Roberts and Meleney 1965), a spray-dip machine has been used to apply whole-body spray to animals. Roberts et al. (1969) fed an animal systemic insecticide to a bovine infested with *Psoroptes* mites.

8. Screwworms

The screwworm fly, once the most important and destructive ectoparasite of livestock in the southwestern and southeastern States, has been the subject of a highly successful eradication program. It was eradicated from the southeastern United States in 1958 but is found annually in small numbers in the southwestern United States when it invades southern areas from Mexico. Research with screwworm larvicides is extremely limited

because of the lack of natural reinfestations and because of the need to prevent artificial infestations from escaping into the environment.

a. Species: The screwworm is *Cochliomyia hominivorax* (Coquerel), the only species of blow flies that invades living flesh.

b. Population Determination: Because of the eradication program, natural populations of screwworms are extremely limited in size and transitory. Therefore, populations of screwworms in wounds are established through the artificial infestation of man-made wounds of cattle. Wounds are inflicted by cutting the skin with a scalpel and scarifying the underlying muscles. The wounds are then infested with newly hatched screwworm larvae. Wounds may be infested at different days before treatment in order to contain larvae of different ages at treatment time (Drummond et al. 1967c).

c. Sample Size: Because of the extreme limitations of reinfestation and the need for prevention of escape of screwworms into the environment, only small-scale tests with larvicides should be conducted within buildings constructed specifically against escape of screwworm flies. Each animal should have 1 or more infested wounds.

d. Examination Times: To determine initial kill, wounds on cattle are examined 24 hr after treatment. If larvae have been killed, the wounds are challenged by applying newly hatched larvae to them at semi-weekly intervals after treatment until wounds are healed or become reinfested. These data will define the length of reinfestation protection period.

e. Controls: It is well known that screwworm larvae will complete their development in a wound. Therefore, in tests with screwworm larvicides, untreated animals are not necessary. Each wound on each animal acts as its own control. Wounds may be treated with a standard treatment in order to determine relative effectiveness of experimental materials.

f. Experimental Design: Effectiveness of treatments for screwworms in wounds is determined by comparing numbers of wounds in which larvae of specific age survive treatment with numbers of wounds infested before treatment. Residual effectiveness is determined by recording number of days before wounds become reinfested.

g. Treatment Techniques: Insecticides may be applied to cattle for the control of screwworm larvae in wounds by dipping and whole-

body sprays or dusts (Wrich et al. 1961, Graham et al. 1959, Drummond et al. 1966, 1967c, Wrich 1961, Wrich and Bushland 1960). In addition, individual wounds may be treated with dusts or smears. Record formulation, final concentration of active ingredient, diluent used, application techniques, and amount of material applied per wound.

B. Test Reporting:

All details of the test should be reported. Such details should include:

1. Identification of test arthropod(s).

2. Breed, age, sex, origin, (weight if necessary) and condition of cattle in test.

3. Location and time of test. Weather conditions if important.

4. Number of animals/treatment group.

5. Formulation of insecticide.

6. Final concentration of active ingredient.

7. Method and rate of application.

8. Application equipment.

9. Infestation rates before and after treatment. Describe technique used to determine infestation rates. The data depend on the test arthropod, e.g., no. lice/animal, no. of cattle grubs/animal, no. cattle with mite lesions/no. cattle examined, no. of adult flies/animal, etc.

10. Difference in infestation rates of treated cattle at a particular examination period after treatment as compared with infestation rates of same cattle before treatment or infestation rates of similar untreated cattle examined at the same posttreatment time. This difference is usually expressed in terms of percent control or percent reduction of infestation.

11. Effects on host (no effect or unnatural effects).

12. Any other comments regarding the test.

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II. Horses

Horses are infested with a number of insect, mite, and tick parasites. These parasites cause damages ranging from general irritation to death of the horse. Many of these parasites are found in large numbers which can be annoying and debilitating to the host. In addition, because of the bloodsucking habits of a number of these parasites, they transmit diseases of horses. To prevent disease transmission, irritation, and death loss, it is necessary to treat horses with insecticides to kill or protect them from these parasites.

A. Treatment and Evaluation Techniques

1. Horse Bots

Horse bots are larvae that hatch from eggs laid by the flies on the front of the breast, neck and head area of horses. These larvae penetrate the lips and live in the mouth area for brief periods and then migrate down the gastrointestinal tract where they attach to the lining of the stomach or small intestine. When mature, larvae leave attachment sites and pass out with the horse manure; they pupate in the manure or ground. Horse bot larvae cause considerable irritation to the lining of the stomach and small intestine, and animals often suffer from colic or other gastric ailments. In addition, the habits of the female flies when ovipositing cause horses to rear, run, and try to avoid the flies. Such actions are often detrimental to the horse.

a. Species: Horses are infested with three species of horse bots: the common horse bot fly, *Gasterophilus intestinalis* (DeGeer), the nose bot fly, *G. haemorrhoidalis* (L.), and the throat bot fly, *G. nasalis* (L.). Adults of the three species, as well as eggs and larvae, can be easily identified. Usually larvae are collected in order to determine species. Life cycles of these three species are essentially similar.

b. Population Determinations: In order to determine populations of horse bot larvae in the gastrointestinal tracts of horses, it is usually necessary to kill the horses and examine the gastrointestinal tracts for attached larvae. As an alternative to killing the horses, horses may be treated with trichlorfon, which causes most of the larvae to detach, and manure from such treated animals can be examined daily to determine the number of larvae expelled from the horses. In tests with first-instar larvae, populations in the gums, lips and tongue are created through artificial infestation procedures, and second-instar larvae at necropsy are recorded to determine populations of bots (Drudge et al. 1972).

c. Sample Size: In small-scale tests, it is necessary to slaughter or examine all of the horses given a specific treatment. In

large-scale tests, it may be possible to slaughter or examine only a representative sample. With the use of the trichlorfon purge, it may not be necessary to slaughter any of the animals. The following sampling regimen is suggested:

No. of Horses per Treatment	No. of Horses Sampled
1-10	All
11-100	20% (minimum of 10)
>100	20

d. Examination Times: It is not possible to determine extent of infestation before treatment. Therefore, horses should be examined at 1 week after treatment. In the interim, numbers of *Gasterophilus* larvae expelled in manure should be counted and recorded daily.

e. Controls (Standard Treatment): Because each animal acts as his own control, it is not necessary to maintain untreated animals. Horses may be given a standard treatment in order to relate the effectiveness of the test treatments with a known standard treatment.

f. Experimental Design: Effectiveness of the treatments is determined by comparing the numbers of *Gasterophilus* larvae expelled from and remaining attached in horses after treatment. The data on expelled larvae can be obtained by counting all of the larvae in the manure for 1 week posttreatment, and data on remaining larvae can be obtained at slaughter or by giving animals a standard treatment of trichlorfon at 1 week after treatment with the test material. At slaughter, unattached larvae found in the large intestine or intestinal ceca are considered dead. The effectiveness of the treatment can be determined by comparing numbers of bots expelled from horses receiving the test treatment with numbers expelled from the same horses after receiving the standard treatment.

g. Treatment Techniques: Horses are treated in a variety of ways with systemic insecticides for the control of *Gasterophilus* larvae.

(1) Stomach Tube: Suspensions, emulsions or solutions of insecticide are pumped into the horse's stomach with the aid of a stomach tube (Drummond et al, 1959). Care should be taken that the tube is in the stomach. Record formulation, final concentration of active ingredient, total amount of liquid administered, and dosage in terms of mg of insecticide per kg of body weight of horse.

(2) Pour-on: Insecticide may be administered as a pour-on of insecticide applied on and brushed into the back of horses (Drummond 1963). Record formulation, final concentration of active ingredient, diluent, total amount of liquid applied, application technique, and dosage in terms of mg of insecticide per kg of horse body weight.

(3) Intramuscular Injection: Horses may be treated with insecticides injected intramuscularly (Drummond et al. 1959). Record formulation, final concentration of active ingredient, diluent, total amount adminstered, location of injection, and dosage in terms of mg of insecticide per kg of body weight.

(4) Feed Treatment: Insecticides may be administered in the feed of horses. Usually horses are not given feed for 24 hr before treatment, and insecticide is mixed with a small amount of feed or grain supplement and given to horses. No other feed is offered until horses have consumed the treated feed. Treated feed may be given for 1 day only (Drummond 1963) or for periods of 2-5 days (Drudge and Lyons 1972). Record formulation, final concentration of active ingredient, total amount of material placed in the feed, number of days fed, and mg/kg dosage. It may be necessary to record also the rate of consumption of treated feed and water during the test.

(5) Mouth Treatments: Insecticides have been administered as gels and paste formulations into the mouth specifically to kill first instar larvae in the mouth area of horses (Drudge et al. 1972). Record formulation, final concentration of active ingredient, diluent, application technique, and dosage in terms of mg of active ingredient per kg of body weight of horse.

2. Ticks, Lice and Mites

Horses are parasitized by a variety of ticks, lice, and mites that suck blood, burrow in the skin, feed on body fluids, and, in general cause considerable damage and irritation to horses. Of special interest is the fact that certain ticks of horses may carry diseases from animal to animal.

a. Species: A number of species of ticks may be found on horses. Included in this list are *Amblyomma americanum*, the lone star tick, *A. maculatum*, the Gulf Coast tick, *Ixodes scapularis* Say, the black-legged tick, and *Otobius megnini*, the spinose ear tick. Of special importance is *Dermacentor albipictus*, the winter tick, that is found in large numbers on horses in the fall and winter months. Also important is *Anocentor nitens* (Neumann), the tropical horse tick; though limited in its distribution

to Georgia, Florida, and southern parts of Texas, it is of significance because it is a vector of equine piroplasmosis. It lives in the ears and nasal diverticulae of horses. Horses are infested with two types of lice; the horse biting louse, *Bovicola equi* (L.) (Denny), and the horse sucking louse, *Haematopinus asini* (L). In addition, horses may be infested with three species of mange or scab mites: a sarcoptic mite, *Sarcoptes scabei equi* (DeGeer), a psoroptic mite, *Psoroptes ovis* (Hering), and a chorioptic mite, *Chorioptes bovis equi* (Hering). In addition, chigger mites may cause severe dermatitis.

b. Population Determinations: To determine populations of ticks on horses, it is necessary to examine body areas of horses for attached ticks (Hoffman et al. 1969). Drummond and Medley (1965) examined the entire breast from the heart girth to the middle of the back to determine populations of winter ticks and blacklegged ticks. Populations of tropical horse ticks were determined by scraping ticks from the ears of horses (Drummond and Graham 1964, Drummond and Ossorio 1966). Populations of biting and sucking lice can be determined by counting or estimating numbers of lice on specific body areas. Populations of mange and scab mites can be determined only by scraping lesions and examining these scrapings under a microscope for mites.

c. Sample Size: In small-scale tests, all of the horses can be examined for ticks, mites, and lice. In large-scale tests, it may be possible to examine only a sample of horses. The following sampling regimen is suggested:

No of Horses per Treatment	No of Horses Sampled
3-10	All
11-100	20% (minimum of 10)
>100	20

d. Examination Times: In tests with ticks, horses were examined at 1 day, 1 week, and 1 month posttreatment (Drummond and Medley 1965). In tests with tropical horse ticks, animals were examined usually at 1 week and often at 2 weeks after treatment (Drummond and Graham 1964). In tests with lice, animals can be examined at 1 day and weekly after treatment. In tests with mange mites, animals can be examined at 1 week and 1 month later after treatment.

e. Controls (Standard Treatment): In order to determine natural fluctuations in populations, one group of horses held in same pasture should not be treated; to relate effectiveness to a known standard one group of horses could be treated with a standard treatment. In tests with the tropical horse tick, one group of animals was usually left untreated in order

to determine effectiveness of treatments (Drummond and Graham 1964). In tests with lice and mites, it is suggested that a group of untreated animals be maintained in a separate pasture.

f. Experimental Design: In tests with winter ticks and black-legged ticks, effectiveness of the treatments was determined by comparing numbers of ticks on treated animals after treatment with numbers of ticks on the same animals before treatment. In tests with tropical horse ticks, effectiveness of the treatments was determined by comparing numbers of dead ticks with numbers of live ticks scraped from ears, or numbers of live ticks scraped from ears of treated horses were compared with numbers of live ticks scraped from ears of untreated horses. Effectiveness of insecticides applied to horses for the control of lice can be determined by comparing populations of lice on treated horses with populations on untreated animals after treatment. Effectiveness of insecticides for control of mange mites can be determined by comparing numbers of horses with infested lesions after treatment with numbers that had infested lesions before treatment or, number of lesions/horse after treatment can be compared with number of lesions/same before treatment.

g. Treatment Techniques: Horses have been treated in a variety of ways with insecticides for the control of ticks, lice, and mites.

(1) Whole-body sprays: Insecticides have been applied with power equipment (Drummond and Medley 1965). Record formulation, final concentration of active ingredient, equipment used (pressures, nozzles, etc.), and volume applied/horse.

(2) Dips: Horses may be dipped in vats charged with insecticides. Record formulation, final concentration of active ingredient (chemical analysis if possible), volume of liquid in vat, amount of insecticide in the charge, number of horses dipped, and information on recharging the vat, if necessary.

(3) Ear treatments: To control tropical horse ticks or spinose ear ticks that live deep in the ears of horses, dusts, mineral oil formulations, smears, and water suspensions or emulsions of insecticides can be applied directly into the ears. The same formulations have been inserted up the nostrils of horses for control of the tropical horse tick (Drummond and Graham 1964). Record formulation, diluent, final concentration of active ingredient, and amount of material applied per horse.

(4) Feed treatment: Tropical horse ticks were controlled in horses given insecticide in the feed for periods of 1-10 days (Drummond and Ossorio 1966). Record formulation used, final concentration of active ingredient in feed (ppm) or dosage mg per kilogram body weight (length of treatment period), and number of horses treated.

(5) Dermal treatments: Horses may be treated dermally with insecticides applied as aerosols, fine mists, by sponge and wipes. Record the formulation, final concentration of active ingredient, application technique, and amount (weight or volume) of material applied per horse.

3. Flies

Horses are parasitized by a number of bloodsucking flies (often called biting flies) that are of particular importance because of the fact that they cause considerable annoyance to horses as well as transmit diseases such as anthrax, habronemiasis, encephalitis, swamp fever, vesicular stomatitis, and anaplasmosis. In addition, horses can be annoyed by face flies that do not bite.

a. Species: Species of biting flies that attack horses include horn flies, *Haematobia irritans*, stable flies, *Stomoxys calcitrans*, and a variety of horse flies and deer flies, black flies, biting midges, and mosquitoes. Each of these species has a unique relationship with horses, and it is necessary to determine species of fly that is the test arthropod. The face fly, *Musca autumnalis*, and often the house fly, *M. domestica* L., are attracted to the moisture about the eyes of horses where they sponge liquids.

b. Population Determination: Because of the fact that biting flies remain on the host only for a short feeding period, it is difficult to determine the populations of these flies on horses. Usually horses are observed for a specific period of time at a specific period of the day, and the numbers of flies that light on the animals and feed are recorded. In tests with face flies, Dorsey (1966) counted numbers of face flies on the face of horses when the face was presented in a frontal view.

c. Sample Size: In small-scale tests, it is necessary to examine all the animals given a treatment. In larger tests, it may be possible to sample only a limited number as follows:

No. of Horses per Treatment	No. of Horses Sampled
3-10	All
11-100	20% (minimum of 10)
>100	20

d. Examination Times: Because insecticides that control (or repel) biting and nonbiting flies on horses are active for only short periods of time, it may be necessary to examine horses within hours after treatment and daily thereafter. In tests with baits or insecticide-impregnated resins

in strand-containing halters, horses may be examined periodically throughout the treatment period for face flies.

e. Controls: Because of the fact that biting flies fly rapidly from animal to animal, treated and untreated horses should not be held in the same pasture. In tests with repellents, Blume et al. (1971) held treated and untreated horses in the same pasture. Dorsey (1966), in tests with the face fly, was able to hold treated and untreated animals in the same pasture. In order to determine relative effectiveness of new treatments, a group of horses may be treated with a standard treatment. With biting flies, horses given a standard treatment should not be held in the same pasture with animals given the experimental treatment.

f. Experimental Design: In tests with horses sprayed with a repellent, one horse was not treated, another horse was treated with a specific amount of spray, and numbers of horse flies lighting and feeding on the treated horse were compared with those on the untreated horse. Examinations were made between 3/4 and 3-3/4 hr after treatment (Blume et al. 1973). In tests with toxicants applied to horses, Blume et al. (1973) confined horses in large cages and released stable flies and horn flies into the cages. Effectiveness of the treatment was determined by comparing numbers of flies released and numbers of flies recaptured from treated horses with numbers released and recaptured from untreated horses. It is extremely difficult to quantitatively evaluate the effectiveness of materials applied to horses to kill and repel flies.

g. Treatment Techniques: Horses may be treated with insecticides in dips, as whole-body sprays, or as fine mist sprays, with toxicants or repellents in aerosols, or as sponge-on or wipe-on applications to control or repel biting flies, [see section II, A, 1, g, (1), (2), (5)].

Other techniques were used to control face flies.

(1) Treated Halters: Dorsey (1966) attached insecticide-impregnated strands to halters worn around the face of horses for the control of face flies. Record formulation of insecticide, final concentration of active ingredient, impregnated material, construction of halter and of treatment carrier, and final amount of insecticide/horse.

(2) Smears and Baits: Dorsey (1966) applied insecticides and repellents as smears and baits onto the face of horses for control of face flies. Record formulation, diluent, final concentration of active ingredient, application techniques, and amount applied/horse.

B. Test Reporting:

All details of the test should be reported. Such details should include:

1. Identification of test arthropod.

2. Breed, color, age, sex, origin, weight (if necessary) and condition of horses in test.

3. Location and time of test (weather conditions if important).

4. Number of animals/treatment group.

5. Formulation of insecticide.

6. Final concentration of active ingredient.

7. Method and rate of application.

8. Application equipment.

9. Infestation rates before and after treatment. The data depend on the test arthropod, e.g., average no. bots/horse, average no. lice/horse, average no. ticks/horse, average no. horses infested with mange/no. horses examined, average no. flies feeding/horse, etc. Describe technique used to determine infestation rates.

10. Difference in infestation rates of treated horses at a particular examination period after treatment as compared with infestation rates of same horses before treatment or infestation rates of similar untreated horses examined at the same posttreatment time. This difference is usually expressed in terms of percent control or percent reduction of infestation.

11. Effects on host (no effect or unnatural effects).

12. Any other comments regarding the test.

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III. Sheep and Goats

Sheep and goats are parasitized by a variety of arthropods that suck blood, live on skin scales and hair or wool, invade tissues, and even live in nasal chambers and sinuses. Control of arthropod parasites is essential to the health and productivity of the animals, for parasitized animals are less productive than parasite-free animals, and heavy infestations may lead to the debilitation or death of the animals.

A Treatment and Evaluation Techniques

1. Sheep and Goat Lice

Sheep and goats are parasitized by a number of biting and sucking lice. Biting lice live on skin debris, hair or wool and may create intense dermal irritation which causes sheep and goats to rub and bite wool and mohair, and as a result the fleece or hair coat becomes matted, ragged, torn, and greatly reduced in value. Often large areas of wool and mohair are rubbed off. Sucking lice damage sheep and goats by withdrawing blood and also cause intense irritation and itching. Often wounds are formed at the sites of irritation, and these wounds may become infected with bacteria and other agents. In general, lice cause reduction in amount and quality of wool and mohair, and heavy infestations may lead to stunting of growth and loss of vitality of the animal.

a. Species: Sheep are infested with the sheep biting louse, *Bovicola ovis* (Schrank), sucking body louse, *Linognathus ovillus* (Neumann), and the sucking foot louse, *L. pedalis* (Osborn). Goats are infested with three species of biting lice -- *Bovicola crassipes* (Rudow) and *B. limbatus* (Gervais), both commonly found on Angora goats, and *B. caprae* (Gurlt), found on Spanish-type goats. Goats are also infested with the sucking lice, *L. stenopsis* (Burmeister) and *L. africanus* (Kellogg and Paine). It is necessary to collect representative samples of lice on treated animals and identify them.

b. Population Determination: The usual method for the determination of populations of lice on sheep and goats is by parting the wool or mohair on one side of the animal's body in at least 5 places, usually on the side of the face, neck, back, side of body and hind leg. The number of motile forms seen in a 1-in. or 2-cm section of the part are recorded. The total count is used to indicate degree of infestation. With goats, it is necessary to differentiate between the three species of biting lice and the two species of sucking lice that may be found scattered over the animal's body. With sheep, the only biting louse encountered will be *B. ovis; L. ovillus* is found particularly on the face and head area but may be found in colonies on the body, and *L. pedalis* is limited in its distribution to lower legs but may infest lower hairy parts of the body, including shanks and belly.

Populations of *L. pedalis* are determined by counting the number of lice on all 4 lower legs. Hoffman et al, (1969) lists the following rating system for all types of lice on sheep and goats:

Total number of lice seen in 5 parts (or total *L. pedalis* on all 4 legs)	Rating
0	Uninfested
1-5	Light
6-20	Moderate
>20	Heavy

c. Sample Size: The number of animals examined depends upon the size of the treatment groups. Suggested sample sizes are as follows:

No. of Sheep or Goats/Treatment Group	No. of Sheep or Goats Examined
3-10	All
11-100	20% (minimum of 10 animals)
>100	20

It is suggested that heavily infested sheep and goats be selected before treatment and marked so that the same animals can be examined after treatment.

d. Examination Times: Test animals should be examined before treatment and after treatment. If 2 treatments are to be tested, animals should be checked at weekly intervals after both treatments. If eradication is the goal, animals may be checked several months to a year after treatment to determine if animals become reinfested before the next shearing.

e. Controls (Standard Treatment): In small-scale tests, a group of untreated animals equal in size to a treatment group and containing animals of the same general description as the treated animals should be left untreated to determine natural changes in populations, and one or more treatment groups may be treated with a standard treatment. Untreated animals and animals treated with standard treatment should be isolated from treatment groups. In large-scale tests, usually all the sheep or goats on the same farm or in the same pasture are treated with the same treatment, and controls may be situated on nearby farms.

f. Experimental Design: Usually treatments are applied after animals are sheared. At the time of treatment, it is important to note length of wool or mohair or interval since last shearing. In most tests,

effectiveness of treatment is based on average numbers of lice on treated animals compared with average numbers on untreated animals at specific intervals after treatment. In other tests, effectiveness is based on numbers of animals infested per group after treatment.

g. Treatment Techniques: A number of techniques have been utilized to apply insecticides to the external surfaces of sheep and goats for the control of lice.

(1) Dip: Sheep or goats may be dipped in a standard rectangular or round dipping vat (Moore et al. 1959). Animals should be completely immersed in the insecticide to thoroughly wet the skin on all body parts. Special care should be taken to submerge the head. Record formulation used, final concentration of active ingredient (chemical analysis if available) and volume of vat fluid, size and type of vat, number of animals dipped, and average amount of vat fluid per animal dipped (record volume before and after animals are dipped.) Also record replenishment rate and time of replenishment.

(2) Spray: Insecticides can be applied as high volume-high pressure sprays or low volume-low pressure sprays (Medley and Drummond 1963). A modification of the low volume-low pressure technique is the application of insecticide to sheep in which the operator uses a sprinkling can to apply the insecticide onto the backs of animals (Matthysse 1967). Record formulation used, final concentration of active ingredient, the equipment utilized, the pressure, nozzle type, average volume per animal, and general techniques of application.

(3) Pour-on: Insecticides formulated in water or as ready-to-use solutions can be applied onto the skin along the backline. Often the sheep are weighed and the insecticide is applied on a specific mg of active ingredient per kg body weight basis. The pour-on treatment usually consists of a volume of ounces of finished treatment/100 lb body weight (45 kg) while lower volume treatment consists of a volume of a few milliliters per 100 lb body weight. Record formulation used, diluent, the final concentration of active ingredient, application technique, the amount applied per animal, and dosage in terms of mg of active ingredient per kg of body weight.

(4) Dust; Insecticides are applied as dusts to sheep by power dusters or by hand. In tests with power dusters, sheep are dusted by driving them through a curtain of dust expelled from a multiple-nozzle power duster (Pfadt and Defoliart 1957) or from a single hand-held nozzle (Wrich 1961). Hand dusting consists of applying dusts by hand or with hand-operated equipment to sheep or goats. Record formulation, final concentration of active ingredient, average amount of dust per animal, equipment used, and average length of time animals are exposed to treatment.

(5) Vapor Action; Darrow (1973) placed dichlorvos-impregnated collars (PVC strips) around the necks of goats and recorded the decline in louse infestations. Collars remain on the animals for many weeks. Record formulation, final concentration of active ingredient, the size or weight of the strip, and site of attachment.

2. Sheep Ked

The sheep ked is a wingless, bloodsucking fly that spends its life in the fleece of sheep and may infest goats pastured with sheep. It causes a reduction in market value of leather, decreased carcass weights, and lessened wool growth (Everett et al. 1971), and is the prime cause of a sheepskin defect called cockle (Everett et al. 1969). General methods for the control of this parasite are to treat sheep dermally with insecticides. A review of the biology and control of keds was presented by Imes (1940) and Kemper and Peterson (1953).

a. Species: The only species is *Melophagus ovinus* (L.), the sheep ked.

b. Population Determination: The methods used to estimate populations of sheep keds on sheep have been extensively reviewed by Nelson et al. (1957), who considered the total live count the only satisfactory method for determining populations. However, adequate estimates of populations of keds can be determined by parting the wool on one side in at least 15 places and counting the number of sheep keds observed in the 5 to 8-cm part. Ratings of relative infestations of sheep keds were presented by Hoffman et al. (1969) as follows:

Total Number of Keds Counted/Animal (15 partings)	Rating
0	Uninfested
1-15	Light
6-15	Moderate
>15	Heavy

c. Sample Size: The number of sheep examined depends upon the size of the treatment group. Suggested sample sizes are as follows:

No. of Sheep/Treatment Group	No. of Sheep Examined
3-10	All
11-100	20% (minimum of 10 animals)
>100	20

It is suggested that heavily infested sheep be selected before treatment and marked so that the same animals can be examined after treatment.

d. Examination Times: Usually sheep are examined before treatment and 1 week and monthly after treatment. Examinations may be made at intervals up to 1 year (next shearing) if eradication is the goal of the treatment (Matthysse 1967).

e. Controls (Standard Treatment): In smallscale tests, usually one group of sheep similar in breed, size, and condition to treated sheep should be maintained as an untreated control. It is important that the untreated sheep do not come in contact with treated sheep. One group may be given a standard treatment. In large-scale tests, usually all the sheep on the same premises are given the same treatment. Untreated controls may be maintained on a nearby farm.

f. Experimental Design: Treatments may be applied once or twice to determine whether eradication can be accomplished. It is important to note whether or not infested sheep were added to the flock during the posttreatment period. Usually sheep are treated after shearing when wool is gone and treatments can be applied directly onto the skin. Condition and length of wool should be recorded as part of the treatment technique, for poor results may result from incomplete or inadequate coverage of sheep with insecticide. Effectiveness of treatments is determined by comparing average numbers of sheep keds on sheep examined before treatment and after treatment. Controls are kept to determine natural changes in population of keds.

g. Treatment Techniques: Those techniques listed in Section III, A, 1, g, (1), (2), (3), (4), and (5), for lice can be used to apply insecticides to sheep for the control of sheep keds. Treatment techniques have been reviewed by Schwardt and Matthysse (1948) and Matthysse (1967). Often sheep are infested with keds as well as lice, and a single test can be conducted to determine effectiveness of insecticides for control of both sheep keds and sheep lice.

3. Scab and Mange Mites

Both sheep and goats are parasitized by several species of mange and scab mites, some of which burrow and tunnel in the other layers of skin, causing considerable irritation. Animals bite, scratch, and rub the infested areas, often causing loss of wool and mohair. Scab or mange mites cause decrease in quantity of wool or mohair, loss in weight and general thriftiness of animals, and death. Evidence of scab mite infestation is the tagging and loss of bits of wool and mohair on fences and other objects. Many times large areas of skin become thickened and covered with wounds or lesions. Often fine wool varieties of sheep are more seriously infested than

coarse wool varieties. A good review of sheep scab etiology, biology, and control was presented by Kemper (1952).

Certain species of mange mites are under quarantine regulations, and proper regulatory authorities should be notified if mange mites are suspected.

a. Species: The most common mite on sheep is *Chorioptes bovis* (Hering), the foot mange mite (Roberts et al. 1964). Sheep may also be infested with the mange mite, *Sarcoptes scabiei* (DeGeer). The common mange mite, *Psoroptes ovis* (Hering), was declared eradicated from the United States in 1973.

Rarely seen in the United States but of considerable importance throughout the world is the itch mite, *Psorergates ovis* Womersley. Goats may be infested with a mange mite, *Chorioptes caprea* (Delafond). It is necessary to examine scab and mange mites under magnification in order to determine species. Sheep and goats may be also infested with demodectic mites, *Demodex ovis* Railliet in sheep and *D. caprae* Railliet in goats; these mites cause follicular or red mange and are usually not treated.

b. Population Determination: The only way to determine infestation of scab and mange mites is to scrape lesions and wounds and examine these scrapings for mites under a dissecting microscope. The number of scrapings per animal is variable, but Downing and Mort (1962) recommends 17 areas. This number can be reduced to 5-6 if the scrapings are taken from animals known to have been infested before treatment (Meleney and Roberts 1967). Usually the scrapings are examined, and examinations are listed as positive or negative for mites. Meleney and Roberts (1967) presented a scoring system ranging from 1 to 8, dependent upon the number and extent of lesions infested with live mites.

c. Sample Size: Numbers of sheep and goats examined depend on the size of the tests. As with tests with lice and keds, the following samples are suggested:

No. of Sheep or Goats/Treatment	No. of Sheep or Goats Examined
3-10	All
11-100	20% (minimum of 10 animals)
>100	20

Because of the difficulty in determining infestations, it is essential that infested animals be identified before treatment and that the same animals be examined after treatment to determine effectiveness of treatment.

d. Examination Times: Usually animals are examined before treatment to insure that they are infested and after treatment at weekly intervals for several months and then monthly thereafter. These long intervals are necessary to allow populations of mites to develop so that they can be detected.

e. Controls (Standard Treatment): In small-scale tests, one group of untreated animals should be maintained to determine natural changes in populations. If possible, one group of animals should be treated with a standard treatment. In large-scale tests, usually all sheep on the same premises are given the same treatment. In most tests, infested sheep given the same treatment should be kept together with one pen and isolated from those receiving other treatments to determine whether treatment killed all the mites. In certain tests (Roberts and Meleney 1971), previously uninfested and treated sheep were placed into flocks that were infested so that the treatments could be challenged by infestation.

f. Experimental Design: Animals may be treated more than once as part of the treatment regimen. It is important to know whether or not sheep or goats are shorn or not shorn and length of time between treatment and shearing. Effectiveness of treatment is determined by comparing numbers of sheep and goats infested per numbers examined with number infested per number examined after treatment. Same animals should be examined before and after treatment.

g. Treatment Techniques: The most common and effective method of treatment is dipping [III, A. 1, g, (1)] (Strickland et al. 1970, Meleney and Roberts 1967). Other treatments have been whole-body sprays. Roberts and Meleney (1971) found that dusting was ineffective. It is extremely important that the treatment be thorough and complete in order to assure that all lesions on the animals are treated.

4. Fleeceworms and Screwworms

Both sheep and goats are attacked by screwworm larvae that invade living tissues. This species has been eradicated from the Southeastern U.S. and is the object of an eradication program in the Southwestern U.S. and Mexico. Sheep and sometimes goats are also attacked by fleeceworms that may live on the skin and in the fleece of sheep and mohair of goats or infest old wounds. These maggots rarely invade living tissue, but live in damp wool or mohair that is soiled with urine or feces. The infested area may become irritated, denuded of wool or mohair, and eventually invaded by bacteria, etc. Fleeceworms in the U.S. are closely related to the species of flies that cause fly strike in sheep - important parasite of sheep in many areas of the world outside of the United States.

a. Species: The primary screwworm that invades living tissue is *Cochliomyia hominivorax* (Coquerel). Fleeceworms that invade fleece and breed in carrion and old wounds are primarily *Cochliomyia macellaria* (F.), the secondary screwworm fly, *Phormia regina* (Meigen), the black blow fly, and *Phaenicia sericata* (Meigen). There may be other species of lesser importance. Often fleeceworms are found in multiple infestations

b. Population Determination:

(1) Screwworms: Because of the eradication program in the United States, natural populations of screwworms are very rarely encountered. Therefore, testing is usually conducted with artificially infested wounds. Animals are wounded by cutting away skin and scarifying exposed flesh, and wounds are infested with newly hatched larvae at specific intervals before treatment (Wrich and Bushland 1960).

(2) Fleeceworms: In order to be assured of infestations, usually the fleece of animals is impregnated with citrated blood (Knipling 1942) or hamburger meat (Graham and Eddy 1948), and this soiled fleece is artificially infested with larvae of fleeceworms. Natural infestations of fleeceworms may be found in the crotch or breech area of sheep in moist environments when the wool is soiled by feces, urine, or rain.

c. Sample Siae: In tests with screwworms and fleeceworms, each animal is inspected before treatment, and extent and deviation of infestation are determined before an animal is included in the test. At least 3-5 infested animals should be treated with the same treatment.

d. Examination Times: Animals are examined usually 1 day after treatment to determine kill of larvae in wounds or in fleece. In tests tht include artificial reinfestation, wounds or fleece are challenged at specific intervals, usually weekly, until wounds become infested or are healed or until fleece becomes reinfested. In large-scale test with fleeceworms, previously infested animals are inspected biweekly or weekly after treatment for natural reinfestations.

e. Control (Standard Treatment); In treatments with screwworms, each wound is its own control in that wounds are examined for initial kill and artificially reinfested until healed. In tests with fleeceworms, each animal is its own control. In most instances, it is possible to place groups of treated sheep in the same pasture with untreated controls and one group of animals that may be treated with a standard treatment and challenged artificially or naturally along with the test animals.

f. Experimental Design: In small-scale tests with screwworms, one day after treatment, wounds are examined for living larvae to determine

residual effectiveness of the treatment. In tests with fleeceworms, all animals should be examined one day after treatment to determine initial kill. If treatments kill all the larvae, in natural reinfestation tests, animals are returned to the pasture and examined weekly to determine extent of reinfestation. In artificial reinfestation tests, animals are challenged weekly with reinfestation and examined carefully to determine whether larvae survive. Effectiveness of initial kill is based on the ratio of numbers of wounds or animals in which all larvae are killed per number wounds or animals originally infested. Effectiveness of residual activity is based on length of time required for wounds or fleeces to become reinfested.

g. Treatment Techniques: Sheep and goats may be treated for control of screwworms and fleeceworms with treatment techniques of dipping, spraying, and dusting [listed in section III, A, 1, g, (1), (2), and (4)]. In addition, the following treatment techniques may be used:

(1) Smear: Insecticides formulated as smears or in ointments may be applied directly into and surrounding wounds containing screwworm larvae. Special care should be taken to treat the area thoroughly. In tests with fleeceworms, smears and ointments may be diluted with water or oil and brushed or otherwise applied onto the entire infested area. Record formulation, final concentration of active ingredient, and amount of material applied per wound or area.

5. Sheep Nose Bots

The larvae of the sheep nose bot fly live on mucous surfaces of the nasal passages and sinuses of sheep and occasionally goats. During warm weather females deposit living larvae onto and in the nostrils of sheep. Infestation of larvae can cause irritation to the nasal passages, and sheep characteristically try to prevent flies from larvipositing by holding their heads near the ground and shaking their heads and stomping their feet. Heavy intestation may cause unthriftiness in sheep; animals may lose condition and become susceptible to secondary infections. Recent studies on life history of the sheep bot fly have been presented by Rogers and Knapp (1973). Early treatments for the control of sheep nose bot larvae in sheep consisted of the irrigation or injection of materials into the nasal passages and frontal sinuses of sheep (Cobbett 1940). Since 1958, sheep nose bot larvae have been controlled by animal systemic insecticides.

a. Species: The only specis is *Oestrus ovis* L., the sheep nose bot fly.

b. Population Determination: The only accurate method for determining numbers of sheep nose bot larvae in sheep is to kill the sheep, split the skulls transversally along a line between the eyes, and examine carefully surfaces of the mucous membranes of the nasal chamber, nasal septa, sinuses, for larvae and record numbers of all three instars.

c. Sample Size: Each animal is an individual treatment. Suggested numbers of sheep slaughtered and examined are as follows:

Number of Sheep/Treatment	Number of Sheep Examined
3-10	All
11-100	20% (minimum of 10)
>100	20

d. Examination Times: Treated sheep are usually slaughtered and examined at 3-10 days after treatment.

e. Control (Standard Treatment): In small-scale tests, one group of sheep equal in number to a treatment group and similar in age, weight, breed, origin, etc., to treated sheep should be left untreated as a control. One treatment group may be given a standard treatment. In large-scale tests, typical animals may be slaughtered immediately before treatment to determine the size of infestation and serve as controls for the test.

f. Experimental Design: If possible, during the period between treatment and slaughter, treated sheep should not be exposed to reinfestation be larvipositing flies. Tests may be conducted after frost when the danger of reinfestation is decreased.

g. Treatment Techniques: The techniques utilized to apply insecticides dermally to sheep and goats for control of lice, keds, and mange are dips, spray, pour-ons and dusts [listed in section III, A, 1, g, (1), (2), (3), and (4)] can be used to apply insecticides to sheep for the control of sheep nose bots. In addition, the following techniques can be used:

(1) Single oral treatment: Sheep may be treated orally with insecticides formulated as drenches, boluses, or in capsules (Peterson et al. 1958, 1960 and Drummond 1962). Record formulation, final concentration of active ingredient, form of treatment, and dosage in terms of mg of active ingredient per kg body weight of sheep.

(2) Feed or water additive: Sheep may be treated with insecticides administered daily in feed or water for a specific period of time (Pfadt 1964). Record formulation, final concentration of active ingredient, amount of feed or water consumed (daily and total), length of treatment period, and dosage either in mg of active ingredient per kg body weight or ppm in feed or water. Animals should be observed closely to be sure that they consume all of the treated feed or water.

(3) Injection: Sheep may be treated with insecticides injected intramuscularly, subcutaneously, or intraperitoneally (Peterson et al. 1959, Drummond 1966). Record formulation, diluent, final concentration

of active ingredient, locus of injection and dosage in terms of mg of active ingredient per kg of body weight of sheep.

(4) Nasal treatments: Insecticides formulated as ointment, smear, aerosols and mist sprays may be applied to the external and internal surfaces of the nostrils or into the nasal chamber to control sheep nose bot larvae (Pfadt and Campbell 1963).

Record formulation, final concentration of active ingredient, exact method of treatment, and amount applied per sheep.

B. Test Reporting

All details of the test should be reported. Such details should include:

1. Identification of test arthropods.

2. Breed, age, sex, origin, weight (if necessary), condition, length of wool or mohair (time after shearing), and condition of sheep and goats in tests.

3. Location and time of test (weather conditions if important).

4. Number of animals/treatment group.

5. Formulation of insecticide.

6. Final concentration of active ingredient.

7. Method and rate of application.

8. Application equipment.

9. Infestation rates before and after treatment. The data depend on the test arthropod, e.g., average number of lice or keds/sheep, number of lesions with mange mites/number lesions examined, number of sheep infested with mange/number examined, number of wounds with screwworms/number wounds, number of sheep with fleeceworms/number sheep inspected, number *O. ovis* larvae of each instar/number sheep heads examined, etc. Describe method of determining infestation rates.

10. Difference in infestation rates of treated animals at a particular examination period after treatment as compared with infestation rate of same animals before treatment or with infestation rates of similar untreated animals examined at the same posttreatment time. This difference is usually expressed in terms of percent control or percent reduction of infestation.

11. Effects on host (no effect or unnatural effects).

12. Any other comments regarding the test.

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IV. Swine

Swine are infested with a limited number of arthropod ectoparasites, lice and mange mites, that suck blood, cause irritation and itching, decreased weight gains and stunted growth. Unlike mange in cattle, sheep and goats, mange in hogs, although a problem to swine and swine herders, is not the object of an eradication campaign and therefore is not subject to quarantine and compulsory treatment. Because of their large size, hog lice are easily detectable on infested animals.

A. Treatment and Evaluation Techniques

1. Hog Lice

a. Species: The only species of lice on swine is *Haematopinus suis* (L.), the hog louse.

b. Population Determination: To determine populations of hog lice on swine, it is necessary to restrain hogs and count numbers of motile forms, including nymphs and adults on the whole body. Special attention should be given to examine legs, eyes, tail and inside the ears. It is preferable to use actual counts of lice. However, infestations were rated by Hoffman et al. (1969) as follows:

No. of Lice per Animal	Rating
0	None
1-5	Light
6-15	Moderate
16 and above	Heavy

c. Sample Size: The following is a suggested sampling size.

No. of Swine per Treatment	No. of Swine Examined
3-10	All
11-100	20% (minimum of 10 animals)
>100	20

It is suggested that heavily infested animals be identified prior to treatment and these same animals be examined after treatment.

d. Examination Times: Animals should be examined before treatment and weekly after treatment. In case of continuous treatment, such as backrubbers, oilers, or premise treatment, animals should be examined before treatment and at frequent intervals during treatment regime to assess effectiveness.

e. Controls (Standard Treatment): Whenever possible in small-scale tests, one group of swine equal to the size of a treated group should be left untreated. If possible, another group should be treated with a standard treatment. Both untreated swine and those given a standard treatment should be isolated from treatment groups. In large-scale tests in which all swine on a farm are given the same treatment, untreated swine should be maintained on neighboring facilities to determine natural changes in populations of hog lice.

f. Experimental Design: Effectiveness of treatment is determined by comparing average numbers of lice on swine before treatment with average numbers of lice on these same animals at intervals after treatment or by comparing average numbers of lice on treated swine with average numbers of lice on untreated swine.

g. Treatment Techniques: Lice can be controlled by applying insecticides to swine or swine holding areas.

(1) Whole body sprays: It is necessary to treat animals thoroughly to point of run-off (Imes 1937). Special care should be taken to treat inside of ears and other difficult-to-treat areas. Record formulation, final concentration of active ingredient, equipment used and application techniques and average volume of spray applied per animal.

(2) Dip: Swine may be dipped in a standard swine dipping vat (Imes 1937), or any container large enough to completely immerse swine. Record formulation, final concentration of active ingredient (chemical analysis if available), volume of liquid in vat, age of charge at time of dipping, number of swine dipped and data on recharging if necessary.

(3) Dust: Dusts can be applied by hand or power duster to all parts of the body with special care to treat the ears. Record formulation, diluent, final concentration of active ingredient and average amount of dust applied per animal.

(4) Pour-on: Insecticides formulated in water or as ready-to-use solutions can be applied to the skin of swine. Treat along backline

of animal with specific volume of dilute insecticide. Record formulation, diluent, final concentration of active ingredient, average dosage in terms of mg of active ingredient per kg of body weight of animal.

(5) Backrubbers or oilers: Standard swine backrubbers or oilers can be treated with insecticide in number 2 diesel oil, light mineral oil, or standard diluent. Place backrubber or oilers at appropriate heights in areas where swine congregate. Record formulation, diluent, final concentration of active ingredient, rate of treatment, volume per meter of backrubber or oiler. If backrubbers or oilers are refilled, record time of retreatment, formulation, concentration of active ingredient, and volume used.

(6) Premise Treatment: Dust, granules or sprays can be applied to bedding, litters, wallows and other areas in the hog lot (Johnson 1961, McGregor and Gray 1963). Record formulation, final concentration of active ingredient, and amount applied (grams or liters/square meter). If areas are retreated, record similar data for retreatment.

2. Hog Mange

a. Species: Common mange in swine is caused by *Sarcoptes scabiei suis* Gerlach. Another type of mange is caused by *Demodex* spp. but demodectic mange usually is not treated.

b. Population Determination: To determine infestation of mange mites, it is necessary to scrape skin and examine scrapings under magnification for live mites. Scraping should be taken from areas that are obviously infested. A minimum of 3 scraping/hog is recommended. Scrapings are designated as either infested or not infested with mange mites (Hixson and Muma 1947).

c. Sample Size: Sample size should be similar to that for hog lice. The following is the suggested sample size:

Number of Swine/Treatment	Number of Swine/Examined
3-10	All
11-100	20% (minimum of 10)
>100	20

It is important to mark heavily infested animals so that these same animals can be examined after treatment.

d. Examination Times: Swine should be examined before treatment and at 1 week, and monthly after treatment. Usually if treatment fails, live mites are found 1 month after treatment. Additional examinations may be warranted to determine whether the treatment eradicates mange (Roberts and Rogoff 1953).

e. Control (Standard Treatment): In small scale tests a group of untreated controls or a group of swine treated with a standard treatment should be maintained on the same farm but should be kept completely isolated from treated animals. In all tests all animals that come in contact with each other should be treated with the same insecticide.

f. Treatment Techniques: Treatment techniques have been limited to those that provide thorough application such as dips and sprays [Section IV, A, 1, g, (1), and (2)].

B. Test Reporting

All details of the test should be reported. Such details should include:

1. Identification of test arthropods.

2. Breed, age, sex, origin, weight (if necessary) and condition of swine in test. Weather conditions (if important).

3. Location and time of test.

4. Number of animals/treatment group.

5. Formulation of insecticide.

6. Final concentration of active ingredient.

7. Method and rate of application.

8. Application equipment.

9. Infestation rates before and after treatment for hog louse control should be recorded in terms of average numbers of lice per hog and with hog mange control, data should be recorded in terms of numbers of swine infested per number of swine examined. Describe technique used to determine infestation rates.

10. Difference in infestation rates of treated animals at a particular examination period after treatment as compared with infestation rate of same animals before treatment or with infestation rates of similar untreated animals examined at the same posttreatment time. This difference is usually expressed in terms of percent control or percent reduction of infestation.

11. Effects on host (no effect or unnatural effect).

12. Any other comments regarding test.

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V. Poultry

Poultry, including chickens, turkeys and a number of domestic fowl, are infested with a variety of arthropod ectoparasites that live on the skin of the birds, chew skin debris and feathers, suck blood, and cause lowered growth rates lessened egg production, and may lead to debilitation and death of heavily infested animals. It is usually necessary to treat poultry with insecticides to prevent massive buildup of populations of these ectoparasites. In addition, poultry houses are the source of a variety of flies that are of considerable nuisance and must be controlled.

The techniques listed for evaluating the effectiveness of insecticides applied to poultry and other fowl in this compendium are limited to those used to evaluate insecticides applied directly to poultry for the control of major arthropod parasites, to litter for the control of major arthropod parasites, to litter for the control of lice and mites, to the ground for the control of turkey chiggers, and to the diet of poultry or to the manure for the control of manure-inhabiting fly larvae. Excluded are treatments for the control of fowl ticks, *Argas* spp., and the fowl mite, *Dermanyssus gallinae* (DeGeer), which are controlled by treating roosts, cracks, and wall and floor surfaces of poultry houses; effectiveness of thes treatments is determined by examining structures in poultry houses rather than by examining the poultry. Also excluded are techniques for evaluating treatments of walls and other surfaces with residual spray and baits for the control of adult flies found in poultry houses.

Also excluded are tests to control rare or minor parasites such as sticktight fleas, *Echidnophaga gallinacea* (Westwood), the scaly leg mite, *Knemidokoptes mutans* (Robin and Lanquetin), and the depluming mite, *Knemidokoptes gallinae* (Railliet). There are a number of other ectoparasites found on poultry, but they are of little economic importance (Bishop and Wood 1939).

A. Treatment and Evaluation Techniques

1. Lice

Poultry are infested with a number of species of biting lice that live on skin and feathers of the host. Although lice are found on all areas of the body, certain species may be more prevalent in a specific area than other species. Although these lice are all biting lice, on the occurrence of excessive feeding and damage to the host, their alimentary tracts may contain blood elements. Heavy infestations of lice may cause considerable injury in that chickens exhibit drooping wings, ruffled feathers, and may even lose weight, produce fewer eggs, and become predisposed to common chicken diseases.

a. Species: The most common species of lice on chickens is the body louse, *Menacanthus stramineus* (Nitzsch). Another common species is the shaft louse, *Menopon gallinae* (L.). Less common species are the head louse, *Lipeurus heterographus* (Nitzsch), the wing louse, *Lipeurus caponis* (L.), and the fluff louse, *Goniocotes gallinae* (DeGeer). Other closely related species of lice may be found on turkeys, geese, ducks, pigeon, and other fowl. When conducting a test, it is necessary to collect samples of lice from test birds in order to determine species composition of the infestation.

b. Population Determination: The most common method of determining populations of lice on poultry is by parting feathers on several places of the body and counting motile forms. Hoffman et al. (1969) suggested parting feathers in 7 places, one each on the vent, neck, back, each wing, and 2 on the breast. Other numbers and locations of partings have been used by Hoffman (1960, 1961), Hoffman and Hogan (1967), and Simco and Lancaster (1965). Hoffman et al. (1969) suggested that lice populations may be rated as follows:

Total No. of Lice Seen	Rating
0	Uninfested
1-10	Light
11-25	Moderate
>25	Heavy

c. Sample Size: It is not necessary to examine all birds in a specific test. The following sample sizes are suggested. Birds that are examined should be randomly selected and typical of birds on test.

No. of Birds Per Treatment	No. of Birds Examined
3-10	All
11-100	10
101-500	10%
>500	50

d. Examination Times: Birds should be examined at least once before treatment and 1 day and weekly after treatment for a minimum of 6 weeks after the last treatment. If multiple treatments are tested, birds should be examined after each treatment and weekly for 6 weeks after last treatment. If continuous treatments are tested, birds should be examined throughout the treatment period.

e. Controls (Standard Treatment): In small-scale tests, one group of untreated controls, equal in number to a treatment group, housed on the same farm or in the same poultry house, and separated adequately to prevent transfer of parasites or of treatment, should be maintained as an untreated control. In large-scale tests in which all birds in a single house or on the same farm are given the same treatment, it may not be possible to maintain untreated controls. If possible, one group of birds in s small-scale test should be treated with a standard treatment. In large-scale tests, this may not be possible.

f. Experimental Design: Effectiveness of treatments is determined by comparing average numbers of lice per bird in treated groups with average numbers of lice per bird in the same groups before treatment or with average numbers of lice per bird on untreated control birds.

g. Treatment Techniques: There are several techniques used to apply insecticides to poultry for control of lice.

(1) Dip: Individual birds may be dipped in insecticide thoroughly so as to wet the feathers to the skin (Bishopp and Wood 1939). Birds should be completely immersed. Caution should be exercised to dip on warm days so as to lessen the untoward effect of the water on the birds. Record the formulation, the final concentration of active ingredient, and the volume used and number of birds treated.

(2) Spray: Insecticides may be applied as sprays directly to the birds (Simco and Lancaster 1965). Individuals may be treated separately, or birds in cages may be treated as a group. Record formulation, final concentration of active ingredient, equipment used, pressure, and the amount of spray applied per individual or group of birds treated.

(3) Mist Spray: Insecticides may be applied as fine mists or fogs directly to birds in cages or birds on the floor (Foulk and Matthysse 1963). Record formulation, final concentration of active ingredient, equipment used, and amount of spray applied per number of birds treated.

(4) Dust: Dusts may be applied by hand or with power dusters directly onto individual birds or groups of birds in cages or on the floor (Linkfield and Reid 1958). Record formulation, final concentration of active ingredient, equipment used, and amount of dust per bird or group of birds.

(5) Floor of Litter Treatment: Insecticides can be applied as mists or fogs, dusts, or granules directly to floor areas, litter, or nest

areas (Hoffman 1960, 1961). Record formulation, final concentration of active ingredient, equipment used, amount of insecticide per square meter of surface treated, and total surface area treated.

(6) Dust Box Treatment: Insecticides formulated as dusts or granules may be placed into dust box containers and chickens allowed to treat themselves (Hoffman and Hogan 1967). Record formulation, diluent, final concentration of active ingredient, amount of material per dust box, length of treatment period, number of birds, and average amount of material used per bird during the treatment period.

(7) Vapor Treatment: Strands, cords, or other devices impregnated with insecticides may be attached underneath or around cages containing infested birds (Simco and Lancaster 1965) or attached directly onto birds. Insecticides volatilize from the impregnated surfaces and kill ectoparasites on birds. Record formulation, impregnated material, final concentration of active ingredient, length or weight of impregnated material per bird or per cage containing a specific number of birds, and length of treatment period.

(8) Oral Treatment: Insecticides may be given to birds in single oral treatments or multiple oral treatments in feed or water (Hoffman 1961, Kraemer and Furman 1959) in order to control lice. Record formulation, final concentration of active ingredient in ppm in feed or water, amount of feed or water consumed, dosage of active ingredient per kg of body weight, and length of treatment period.

2. Fowl Mites

Fowl mites spend their life cycles on poultry and are controlled by applying insecticides to birds, or to litter or nesting material that come into direct contact with the birds. Fowl mites suck blood and cause considerable injury to birds. Often birds become heavily infested with fowl mites, and such infestations may lead to lowered egg production, lowered vitality, and often to the death of birds (Combs and Lancaster 1965).

a. Species: The most common species of fowl mite is the northern fowl mite, *Ornithonyssus sylviarum* (C. and F.). Another much less common species is *O. bursa* (Berlese), the tropical fowl mite.

b. Population Determination: Common methods of determination of populations are to count or estimate numbers of motile forms of fowl mites seen when parting feathers in one place on the vent area. Because populations of fowl mites may reach very high levels that cannot be counted, most researchers have used a scale system based on number of mites and feather

discoloration in the vent area to express the degree of infestation (Linkfield and Reid 1958). The following, a modification system of Simco and Lancaster (1965), is suggested as a guide to scales and infestation rates:

Scale	No. of Mites	Rating	Feather Appearance
0	0	None	Normal
1	1-20	Light	Normal
2	20-1000	Moderate	Greying
3	>1000	Heavy	Blackened

c. Sample Size: As with poultry lice tests, all birds in small-scale tests should be examined. Samples can be taken from animals as follows:

No. of Birds per Treatment	No. of Birds Examined
3-10	All
11-100	10
100-500	10%
>500	50

It is helpful to mark heavily infested birds so that these can be examined after treatment.

d. Examination Times: Usually birds are examined once before treatment and at 1 day and weekly after treatment for at least 8 weeks. If multiple treatments are used, birds should be examined after both treatments to determine relative effect of the treatments. Most critical, however, are the examinations after the last treatment. If continuous treatments are used, birds can be examined during the treatment period.

e. Controls (Standard Treatment): Usually one or more groups of untreated animals are maintained in the same house or on the same farm in order to determine natural fluctuations in infestation rates on these control animals. If possible, one group of birds should be treated with a standard treatment. Because of the mobile nature of these mites, it is necessary to be very careful about separating untreated controls from treated birds and birds treated with a standard treatment from untreated birds or birds treated with the experimental materials. In large-scale tests, when all birds on the same farm are treated with the same treatment, no untreated controls can be maintained and each bird serves as its own control.

f. Experimental Design: Effectiveness of treatments is determined by comparing average scale ratings of mites per bird or group of birds given the same treatment with the average scale ratings of these same birds before treatment or with average scale ratings of untreated control birds.

g. Treatment Techniques: The same techniques used to apply insecticides to poultry or litter for the control of poultry lice can also be used to control northern fowl mites. (See Section V, A, 1, g.)

3. Turkey Chiggers

In certain areas of the southern United States, turkeys on range are infested with a turkey chigger, *Neoschongastia americana* (Hirst). The chiggers cause downgrading of turkeys because of loss due to the need at processing time to trim from the skin the feeding lesions formed at the site of attachment of turkey chiggers. Feeding lesions take 3 or 4 weeks to heal after chiggers have been eliminated. General information on importance and biology of *N. americana* has been presented by Kunz et al. (1969) and Everett et al. (1973).

a. Species: Only *Neoschongastia americana* is of importance.

b. Population Determination: Because chiggers attach in large numbers in feeding lesions, numbers of chiggers on turkeys are not counted; rather skin on the leg, thigh, breast, and vent is examined for feeding lesions. The total number of lesions per bird is used as an estimate of the chigger population (Kunz et al. 1969).

c. Sample Size: In small-scale tests, usually all turkeys are examined for lesions. In larger-scale tests, it is necessary only to examine a representative sample. A suggested sample is as follows:

No. of Turkeys/Treatment	No. of Turkeys/Examined
3-10	All
11-100	10
101-500	10%
>500	50

d. Examination Times: Turkeys should be examined for lesions at least once before treatment to determine extent of infestation and then examined weekly after treatment for periods of 4 weeks or until all of the lesions have healed.

e. Controls (Standard Treatment): In small-scale tests, it is necessary to have similarly handled turkeys confined to untreated soil in order to determine the natural fluctuations in populations during the test period. If possible, one group of turkeys should be confined onto soil treated with a standard treatment. In large-scale tests, it may not be possible to have untreated turkeys on the same farm; if convenient, a group of turkeys should be maintained on nearby untreated ground (Kunz et al. 1972).

f. Experimental Design: Effectiveness of a treatment is determined by comparing the numbers of lesions on treated turkeys with the numbers of lesions on the same turkeys before treatment or with numbers of lesions on turkeys confined to untreated ground (Kunz et al. 1971). In small-scale tests, it was necessary to surround treated areas with 10- to 15-ft. protective barrier to prevent chiggers from migrating into treated areas from adjacent untreated areas (Price and Kunz 1970).

g. Treatment Techniques: Insecticides may be applied directly onto turkeys by the techniques used to apply insecticides to poultry for the control of lice and mites (see section V, A, 1, g). Price and Kunz (1970) reported failure of treatment in feed to control chiggers. Most commonly, treatment usually consists of applying insecticides as granules, dusts and sprays to turkey-grazing areas. Insecticides are usually applied at high rate of active ingredient and high volume of material per acre. In small-scale tests, insecticides may be applied by hand; in large-scale tests, power equipment may be used to thoroughly saturate the turkey-grazing areas. Record formulation, final concentration of active ingredient, amount applied per area treated, equipment used, and number of birds on treated areas.

4. Manure-Inhabiting Fly Larvae

Poultry manure, especially that which accumulates under caged layers, is usually infested with larvae of several species of flies. There are two general methods utilized to control fly larvae in poultry manure. One is the topical application of insecticides to poultry manure; the other is the addition of insecticides to the feed or water, of poultry. The insecticide becomes incorporated with the poultry manure and thus is toxic to the larvae. However, the most effective method used to eliminate poultry fly problems is to remove poultry manure from poultry houses at short intervals so that there will be no accumulation and thus eliminate the larval medium. An excellent review of the use of larvicides was presented by Miller (1970).

a. Species: There are several species of flies whose larvae develop in poultry manure. Typically, manure is infested with larvae of the house fly, *Musca domestica* (L.), little house fly, *Fannia canicularis* (L.), the costal fly, *F. femoralis* Stein, and the false stable fly, *Muscina stabulans* (Fallen). In addition, other fly larvae may be found. In order

to determine species composition, it is necessary to collect infested manure, allow flies to emerge from the sample, and count and identify these flies.

b. Population Determinations: Collect a standard volume or weight of fresh manure. Place the sample in a suitable container and record numbers and species of flies that emerge from the sample. In certain tests with larvicides applied to manure, populations of larvae were determined by counting the number of larvae in manure samples (Bailey et al. 1970); in other tests, fly populations were assessed by counting live adult flies and fly specks (Matthysse and McClain 1973).

c. Sample Size: The following is a suggested number of samples to use in conducting insecticide-feed additive trials:

No. of Birds per Treatment	No. of Manure Samples
3-10	3
11-100	10% (minimum of 3 samples)
>100	10

With typically-applied larvicides, Bailey et al. (1968) collected 10 samples, each 1 spoonful, from 10 locations where heaviest infestations of larvae were observed.

d. Examination Times: Samples should be collected at least once before treatment and collected once or twice per week after treatment. In long-term tests, samples may be taken biweekly.

e. Controls (Standard Treatment): In small-scale tests with feed or water additives, one group of untreated birds equal in size to a treated group and housed in the same house or on the same farm should be maintained to collect untreated manure. If possible, a standard treatment should be given to a group of birds equal in size to a treated group. In larger-scale tests, suitable controls may not be maintained on the same farm, but could be maintained on similar nearby farms.

In tests with typical larvicides, one plot of manure may not be treated or treated with water only. One plot may be treated with a standard treatment.

f. Experimental Design: Two types of experiments can be conducted with feed or water additives for the control of manure-inhabiting fly larvae. One utilizes the bioassay technique in which a known number of fly eggs or newly-hatched larvae are placed on a specific weight or volume of manure collected from treated and untreated birds or to be treated birds

before treatment (Miller et al. 1975, Sherman and Ross 1960). Manure should be frozen before bioassay in order to kill unwanted arthropods. After artificial infestation, the samples should be held in containers so that emerged adults can be collected. The second type of test involves utilization of natural reinfestation and is essentially similar to the bioassay technique except that samples of manure are not frozen but are naturally infested in the field and held to determine numbers of flies that emerge. Effectiveness of treatments is determined by comparing numbers of adults collected from treated manure with numbers collected from untreated manure.

In tests with larvicides applied to manure, manure sample are taken after treatment and numbers of larvae counted or numbers of adults that emerge are compared with numbers counted or emerged before treatment or with numbers emerging from untreated manure.

g. Treatment Techniques: Poultry may be treated orally with insecticides added to the feed or water. Insecticides may be added to all the feed or water provided the birds (Miller et al. 1975) or insecticides may be given on a mg/kg basis, and each day's treated feed or water must be consumed before untreated feed or water is provided. Record formulation, final concentration of active ingredient in ppm or percent in feed or water (Morgan et al. 1975), amount of active ingredient consumed per bird or weight of bird, and length of treatment period.

In testing manure with larvicides, insecticides may be applied as conventional sprays, low-volume sprays or mists, and dusts or granules directly onto the manure (Matthysse and McClain 1973, Bailey et al. 1968, 1970, Axtell 1970). Record formulation, final concentration of active ingredient, amount applied per square meter of manure, equipment used, and treatment pressures.

B. Test Reporting:

All details of the test should be reported. Such details should include:

1. Identification of test arthropods.

2. Breed, age, sex, origin, weight (if necessary) and condition of birds in test. In tests with manure record depth of manure cones, consistency, and time of last clean out.

3. Location, type of poultry house, and time of test. Weather conditions (if important).

4. Number of birds/treatment group.

5. Formulation of insecticide.

6. Final concentration of active ingredient.

7. Method and rate of application.

8. Application equipment.

9. Infestation rates before and after treatment. The data depend on the test arthropod, e.g., no. lice/bird, score of mites/bird, no. chigger lesions/bird, no. of adult flies or larvae/manure sample, etc. Describe methods used to determine infestation rates.

10. Differences in infestation rates of treated birds (or manure) at a particular examination period after treatment as compared with infestation rates of same birds (or manure) before treatment or infestation rates of similar untreated birds (or manure) examined at the same posttreatment time. This difference is usually expressed in terms of percent control or percent reduction of infestation.

11. Effects on host (no effect or unnatural effects).

12. Any other comments regarding the test.

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